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U.S. FISH AND WILDLIFE SERVICE  
Division of Ecological Services  
Sacramento, California

SACRAMENTO RIVER  
CHICO LANDING TO RED BLUFF PROJECT  
1984 JUVENILE SALMONID STUDY

by  
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Prepared for  
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## INTRODUCTION

This study was conducted by the Fish and Wildlife Service for the Sacramento District, U.S. Army Corps of Engineers. The purpose of the study was to assess the relationship of juvenile chinook salmon (Oncorhynchus tshawytscha), to the construction of rock revetment type bank protection (i.e., riprap). The study was conducted in the upper Sacramento River between Red Bluff and Chico Landing. While extensive bank protection work has already been completed in the study area, plans currently under consideration call for the construction of a "channel stabilization" project. In contrast to past practices where eroded sites were individually evaluated and bank protection implemented if feasible, this plan would entail the construction of bank protection on the outside of all river bends. Approximately 40 percent of natural river bank in the project area would be converted to rock revetment. This would substantially change the character of the river in the affected area.

The annual chinook salmon run in the upper Sacramento River numbers about 100,000 adults. About half of these fish spawn below the Red Bluff Diversion Dam, in the area proposed for extensive bank protection. There is concern that modification of the banks by placement of rock revetment will adversely affect rearing habitat for juvenile salmon. The impacts of rock revetment were evaluated in a study conducted by the California Department of Fish and Game in 1983 (Shaffter, et al.). That

study indicated that the placement of rock revetment for bank protection reduced the density of juvenile salmon and steelhead trout in nearshore areas. Our study was conducted to augment the existing information on the interaction of juvenile chinook salmon and rock revetment.

#### STUDY AREA

The study area consisted of two river reaches, one near Red Bluff Diversion Dam in Tehama County and the other near Chico Landing in Butte County (Figure 1). Land use along the river is predominantly agricultural, consisting of orchards and row crops. Natural riparian vegetation occurs along the river, although it has been considerably reduced from historical levels.

The river between Red Bluff Diversion Dam and Chico Landing is sinuous with braiding and anabranching tendencies. Throughout the reach, a pool-riffle sequence is present. Generally, riffles occur either in crossover areas between meander bends or in anabranching areas, with pools located in the meander bends. The riverbed is sand, gravel and cobbles. Bank erosion is a natural phenomenon along the river. This erosion, along with the deposition of eroded materials, creates ever-changing stream habitats, including gravel bars and backwater areas.

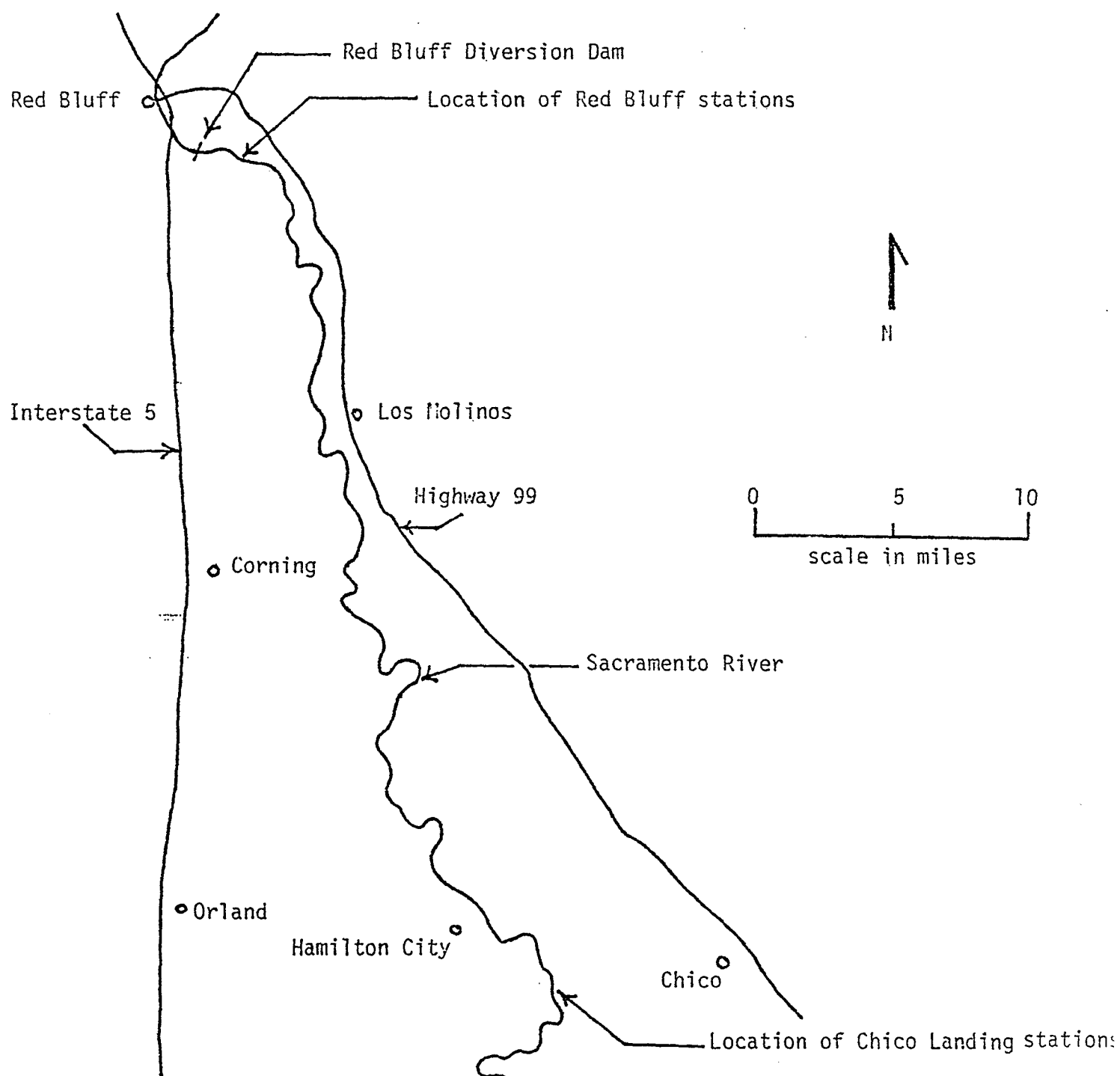


Figure 1. General location of overall study area and study stations.

Locations of all sites at which juvenile salmon were collected for purposes of the study are in Figures 2 and 3. At these locations, sampling stations were established adjacent to both conventionally constructed (one vertical to two horizontal) bank protection works and to unprotected, eroding banks (designated as controls). Sampling stations were also established upstream, downstream, and across from each primary sampling station. The purpose of these additional stations was to ascertain the general distribution of juvenile salmon within each study reach. Illustrations of typical sampling stations are presented in Figures 4 to 7.

Sampling stations (designated as RM215 and RM227) were also established at two locations where standard construction had been modified to provide salmonid rearing habitat. The modification consists of a bench constructed within the standard 1V:2H slope. The benches have a 1V:5H slope and are covered with 1- to 4-inch gravel. The benches are designed to be partially submerged at a flow of 6,000 cfs and completely submerged at 14,000 cfs. Unfortunately, these sites could not be assessed for salmon utilization because they were not inundated during the study period.

The study stations are listed by location and habitat type in Appendix A.

#### METHODS AND MATERIALS

A 16-foot, flat-bottomed boat equipped with electroshocking gear was used to sample the fish population. Samplings were conducted two or three times per week during April and May 1984. Each station was

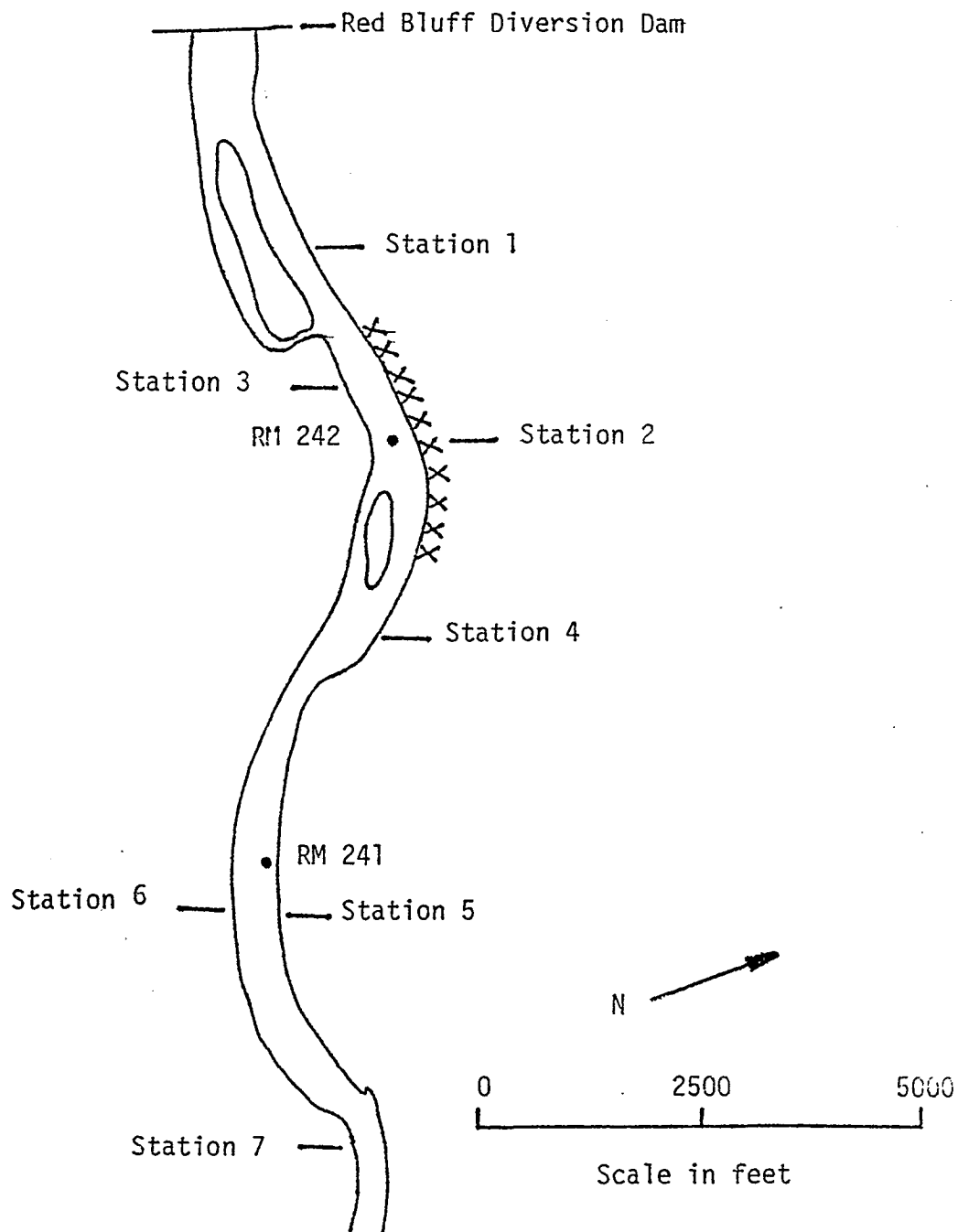


Figure 2. Location of study stations at Red Bluff study area.

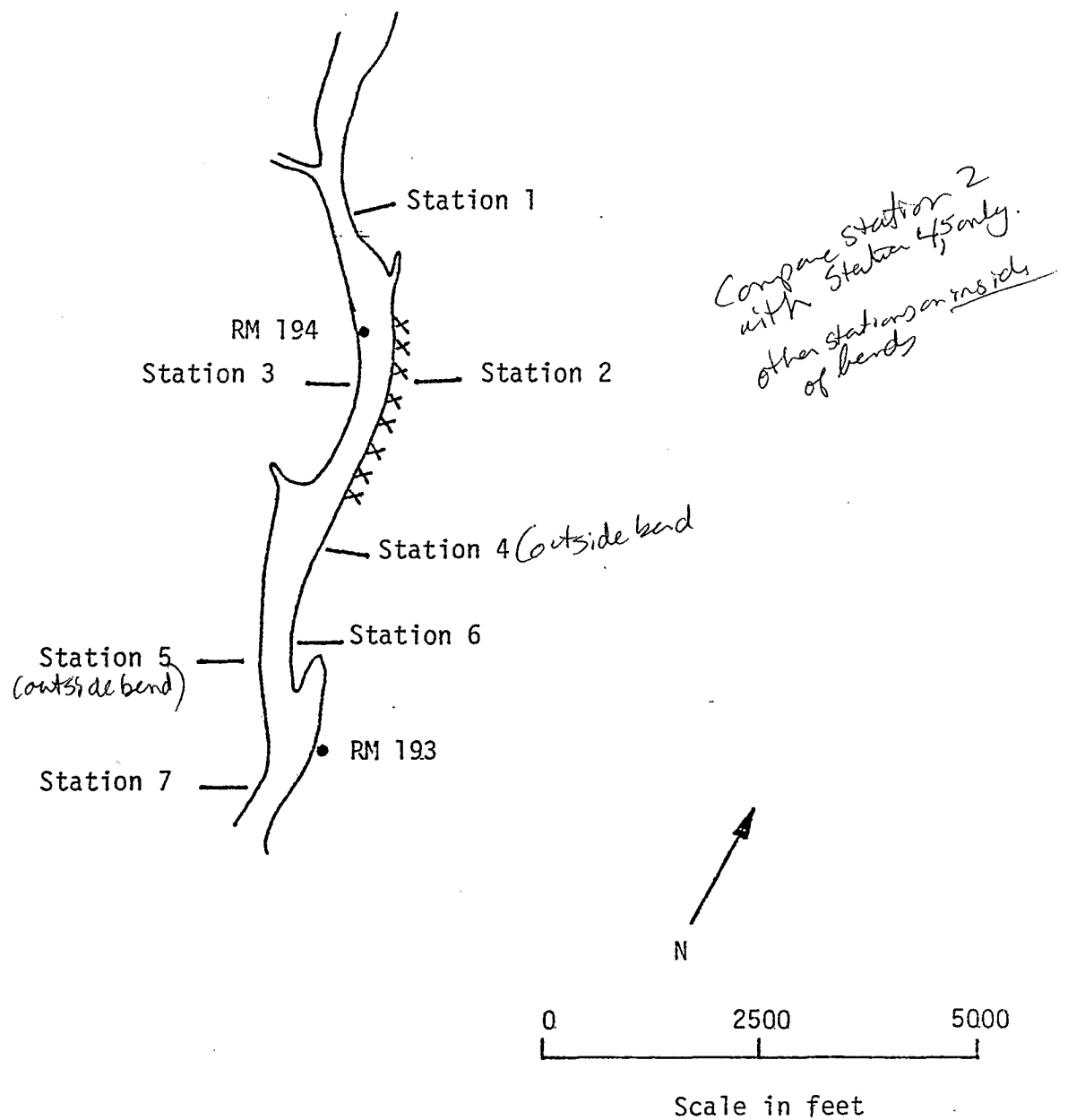


Figure 3. Location of study stations at Chico Landing study area.



Figure 4. Standard rock revetment bank protection placed at River Mile 194R near Chico Landing.



Figure 5. Eroding Orchard at River Mile 241R below Red Bluff Diversion Dam. Juvenile salmon were frequently collected behind snags in this habitat type.



Figure 6. Eroding riparian bank at River Mile 242.5 below Red Bluff Diversion Dam. The greatest number of juvenile salmon were collected in this habitat type.



Figure 7. Standard bank protection with incorporation of 1H/5V bench to provide salmonid rearing habitat. Flow is approximately 5900 cfs and no water is actually on bench.

subdivided into four segments, measuring 150 feet in length. In areas where the habitat type was limited in length, the segments were continuous; in areas where the length of habitat type allowed, the segments were spaced 150 feet apart. Each sampling consisted of making one pass with the electrofishing boat near the shore and parallel to the bank. Two netters were stationed at the bow of the boat to collect fish. In the early part of the study, all stunned fish were counted and identified before release. As netters gained proficiency in identification, collection of non-salmonid species was terminated. Fork length (mm) was determined for representative subsamples of salmon collected at each site.

In addition to electrofishing, a fifty-foot bag seine was used to sample gravel bar and riprap stations. This was done for two purposes: first, to determine if salmon were avoiding the electrofishing boat, and secondly, to assure adequate sampling of gravel bar habitat. The electroshocking boat could not be maneuvered in the shallow water over gravel bars. Seine hauls were made for a distance of about 100 feet parallel to the bank.

Water depth and rate of flow measurements were made at eight representative locations at each station to ascertain any correlation between these factors and salmon abundance.

Sampling results obtained from the eroding bank (control) and riprap stations on the outward bends of the river were analyzed through standard parametric statistics. Catch per unit effort for each station was determined by calculating the average number of salmon collected per hundred feet. Comparisons were made between stations through calculations of analysis of variance.

*\* what type?*  
Results obtained from the inside bends (gravel bars) of the river were not analyzed statistically because the shallow waters prevented efficient sampling of the nearshore area. Sometimes, the boat had to be operated as much as 50 feet from shore. Conversely at eroding banks and riprap areas, fish were often virtually trapped between the bank and the boat. Also, fish near eroding banks favor certain types of cover, thus facilitating their capture. For these reasons, we believe that the samples obtained from shallow water areas (gravel bars) are not directly comparable to samples obtained from nearshore areas with steep banks. On the other hand, fish at eroding bank (control) and riprap sites are about equally vulnerable to capture by electroshocking.

## RESULTS

The Red Bluff stations were sampled on 12 occasions; the Chico Landing stations on 13. The number of salmon collected at each station per sampling is presented in Appendix B. Because the electroshocking equipment malfunctioned during the early part of the study, the data gathered from April 3 to April 10 is not considered valid and was not utilized in our analysis.

Results of the study indicate that juvenile salmon frequent the waters at riparian sites to a greater extent than at either control or riprapped sites. Table 1 presents the total number of juvenile salmon collected at the outside bend stations during the period analyzed.

Table 1. Number of juvenile salmon collected at the outside bend stations

	Red Bluff					Chico Landing			
Station:	1	2	4	6		2	4	5	
Date	Habitat Type:	rip- arian	rip- rap	rip- arian	grading orchard con- trol	Avg rip	rip- rap	rip- arian	herbaceous con- trol
4/19		28	1	21	4	24	0	31	9
4/20		34	0	15	3	24	1	2	3
4/24		30	1	6	34	18	1	6	2
4/25		85	2	64	52	74	1	3	3
5/1							1	11	21
5/2		55	4	106	16	80	1	20	3
5/7		57	1	30	14	44	0	9	15
5/8		60	5	74	16	67	0	5	9
5/9		43	2	68	3	56	4	10	10
Total		392	16	384	194	388	129	97	75

Figure 8 depicts the average number of salmon collected at each of these habitat type stations. Abundance of juvenile salmon relative to the habitat types is presented in Table 2. As evidenced by the preference indices, water adjacent to naturally vegetated banks are much preferred by juvenile salmon.

Within the category of eroding banks, the greatest number of salmon were consistently found at those stations with riparian vegetation. Along eroding banks, the majority of juvenile salmon were found immediately downstream of in-river cover, consisting of snags and the tops of fallen trees.

An analysis of variance (Appendix C) indicates a highly significant difference in numbers of fish at riprapped stations versus control stations at both Red Bluff ( $P < 0.025$ ) and Chico Landing ( $P < 0.01$ ). An additional analysis compared the numbers of fish at riparian stations with riprapped stations. This difference was also found to be highly significant ( $P < 0.01$ ) at both the Red Bluff and Chico Landing study areas.

Seine hauls at the riprapped stations yielded no fish. While this may be simply reflect the paucity of fish in this habitat type, the inefficiency of seines in rock revetment is also a factor. Given the steep drop-off in water depth, and the large rocks in the substrate, fish can easily avoid the net. We believe that electroshocking in this habitat type yields an unbiased sample of the entire fish populations, because numerous species were collected, and conditions for collecting were perhaps the optimum of all habitat types.

Figure 8. Average number of juvenile salmon collected at sampling stations between April 19 and May 9, 1984.

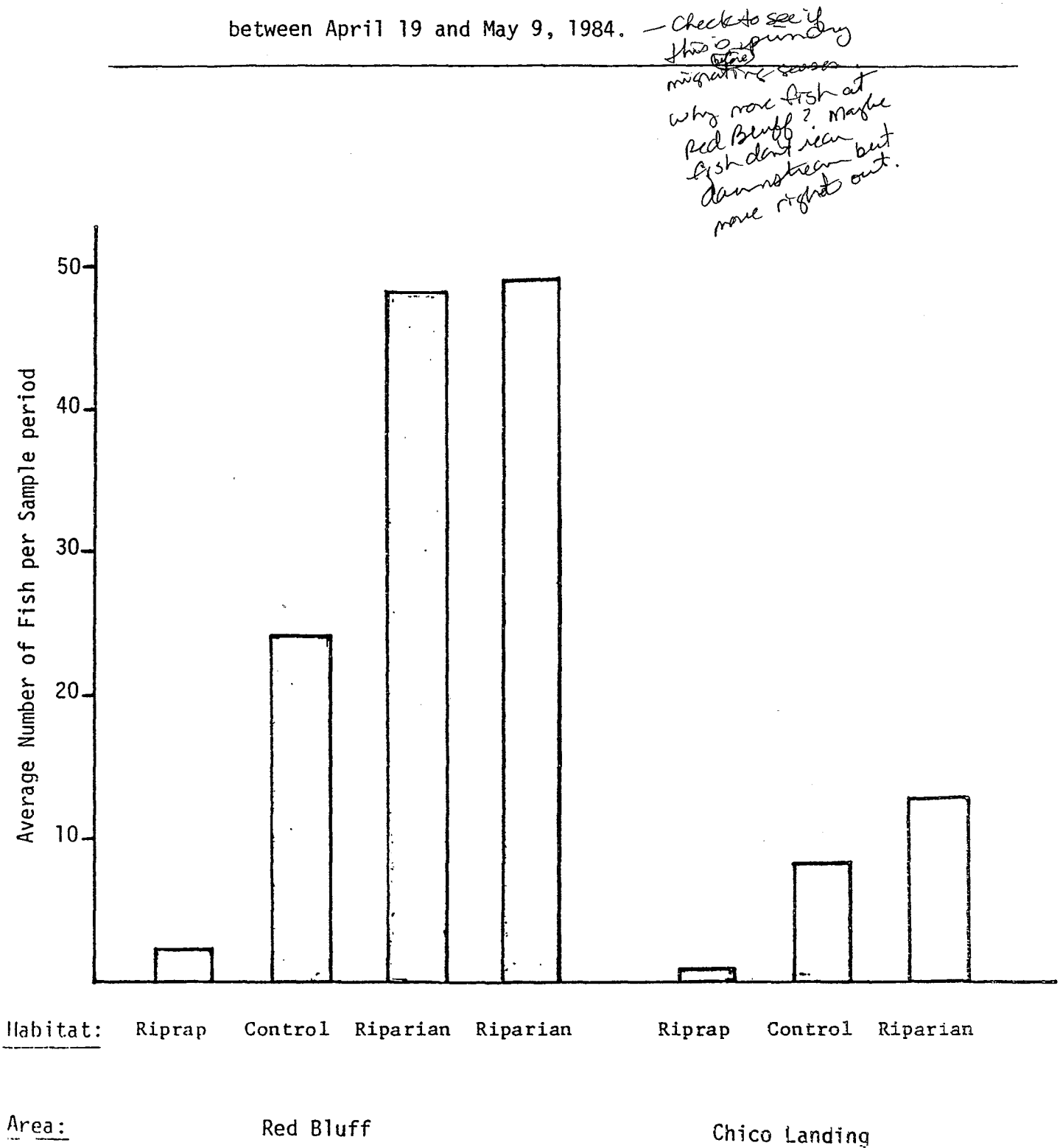


Table 2. Relative preference of juvenile salmon for three habitat types at Red Bluff and Chico Landing stations (April 19 to May 9, 1984)

Habitat Type	Total number of stations	Percentage of stations	Total number of salmon	Percentage of salmon	Preference* Index
Riparian (eroding banks)	3	42.8	873	75	1.75
Control (eroding banks)	2	28.6	269	23	0.80
Riprap	2	28.6	28	2	0.07

\*Preference index =  $\frac{\% \text{ of fish in habitat type}}{\% \text{ of habitat type available}}$

At the gravel bars, far fewer fish were captured by electroshocking than by seining. This demonstrated that juvenile salmon, even though numerous, avoided the electrofishing boat in this habitat type.

#### DISCUSSION

This study measured the relative degree of use by juvenile salmon of three types of aquatic habitat occurring at outside river bends: rock revetment (riprap), eroding agricultural lands (orchards and row crops), and eroding riparian vegetation. Of these habitats, that adjacent to riprap yielded the lowest number of juvenile salmon when sampled by electrofishing. Juvenile salmon were captured in eroding bank habitat, particularly eroding riparian habitat, in much greater numbers than in riprap habitat. The habitat requirements of juvenile chinook salmon afford an explanation for the differences in utilization.

Environmental conditions essential for good juvenile salmon rearing habitats are: suitable water velocity and depth, proper substrate, cover in the form of overhead turbulence or stationary objects, and preferred density of conspecific and other fishes (Edmundson et al 1968). Each of these conditions, plus adequate food and satisfactory water quality, must be present to support populations of juvenile chinook salmon (Everest and Chapman 1972, Reiser and Bjornn 1979, Thompson 1972).

Adequate cover is critical to juvenile salmon rearing because first, it provides protection from predators, and second, it provides feeding stations in slow-moving water adjacent to faster water where drift organisms abound (Allen 1969, McFadden 1969, Butler 1968, Lewis 1969). Very young salmon prefer waters of slow velocities and shallow depths, moving to faster and deeper waters as they grow (Chapman and Bjorn, 1969). Lister and Genoe (1970) found that chinook salmon fry preferred habitats having back eddies, fallen trees, undercut roots, and other protective features. Submerged cover, such as rocks, logs, aquatic plants, and undercut banks provide a refuge from piscivorous predators while overhead cover, such as riparian vegetation, shade, and surface turbulence, help to conceal juvenile salmon from avian and terrestrial predators.

Riparian vegetation is a major source of food energy, shedding plant debris and terrestrial invertebrates. Shaffter (1983) found that terrestrial insects are a major food item of young salmon in the Sacramento River.

Ideally, fish communities present in salmonid streams are low in species diversity and competition and predation are therefore not of major importance. In the study areas, however, Sacramento squawfish (Ptychocheilus grandis), hardhead (Mylopharodon conocephalus) Sacramento sucker (Carostomus occidentalis), prickly sculpin (Cottus asper), tuleperch (Hysterocarpus traski) and members of the Centrarchid (bass and sunfish) family were found in both eroding bank and riprapped habitats.

More Sacramento squawfish and prickly sculpin were found at riprapped stations than at eroding bank stations. *salmon predator?*

Water adjacent to riprapped banks may be described as monotypic habitat having a rocky substrate ascending from the river bottom at a gradient of two horizontal to one vertical. Flow is turbulent directly above the substrate and becomes laminar farther off the substrate. Shaffter, et al., (1983) postulated that the turbulence caused by the rocky substrate presents feeding problems for juvenile salmon. Protruding portions of rocks and the spaces between rocks provide the only form of cover. The removal of riparian vegetation during the installation of riprap eliminates overhead and submerged cover. This reduction in cover, along with the deepening of the water associated with riprapping, reduces the value of near-shore areas for salmon rearing. In addition, the greater numbers of Sacramento squawfish and prickly sculpin in riprapped water habitats impact juvenile salmon adversely by reason of competition for food and space, and possibly predation. Prickly sculpin were found to be particularly abundant in the rocky substrate. Crayfish may also depress salmonid densities in riprap. Extensive populations of crayfish have been documented for riprapped banks along the lower Sacramento River.

Food availability in riprapped water areas is less than optimum because of limited surface area of large substrate, rapid increase in water depth, and high water velocity. Invertebrate production decreases when substrate size becomes greater than gravel-rubble (1½ inch 12 inch). Water velocities over riprap are too turbulent, and possibly too swift, for juvenile salmon to feed effectively on drift organisms.

## CONCLUSIONS

Based on these findings, and those of the California Department of Fish and Game (Shaffter, et al., 1983), we expect rearing habitat for salmon, as well as for steelhead trout, to diminish as more riprap is applied to the banks of the Sacramento River. Salmon originating from the Sacramento River are a highly valued commercial and recreational resource. Their population has been significantly reduced in recent years for reasons that are not fully understood. Nonetheless, it is incumbent upon those concerned with protection of this resource to reduce or eliminate those habitat alterations that are known to depress salmon abundance. Efforts should continue to develop means of alleviating identified impacts.

## Literature Cited

- Allen, K.R. 1969. Limitations on production in salmonid population in streams, p. 3-18 In T.G. Northcote (ed.), Symposium on salmon and Trout in Streams. H.R. McMillian Lectures in Fisheries, Univ. B.C., Vancouver.
- Butler, R.L., and V.M. Hawthorne. 1968. The reactions of dominant trout to changes in overhead artificial cover. ~~Trans. Am. Fish.~~ Soc. 97(1):37-41.
- Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. Am. Nat. 100:345-357.
- Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding, p. 158-176. In T.G. Northcote (ed.), Symposium on Salmon and Trout in Streams. H.R. McMillian Lectures in Fisheries, Univ. B.C., Vancouver.
- Edmundson, E., F.H. Everest, and D.W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. J. Fish. Res. Board Can., 25(7):1453-1464.
- Elser, A.A. 1968. Fish populations of a trout stream in relation to major habitat zones and channel alterations. Trans. Amer. Fish. Soc. 97(4):389-397.

- Everest, F.H. and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Board. Can. 29(1):91-100.
- Lewis, S.L. 1969. Physical factors influencing fish populations in pools of a trout stream. Trans. Am. Fish. Soc. 98(1):14-19.
- Lister, D.B. and H.S. Genoc. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) in the Big Qualicum River, British Columbia. J. Fish. Res. Board. Can. 27(7):1215-1224.
- McFadden, James T. 1969. Dynamics and regulation of salmonid populations in streams, p. 313-329 In T.G. Northcote (ed.), Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries, Univ. B.C., Vancouver.
- Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in the Western United States and Canada; 1. Habitat requirements of anadromous salmonids. USDA Forest Service, General Technical Report PNW-96. 54 p.

Schaffter, R.G., P.A. Jones, and J.G. Karlton. 1983. Sacramento river and tributaries bank protection and erosion control investigation evaluation of impacts on fisheries. California Department of Fish and Game, final report. 93 p.

Thompson, K. 1972. Determining stream flows for fish life. In Proceedings Instream Flow Requirement Workshop, Pac. Northwest River Basin Comm., Vancouver, Wash. p. 31-50.

Appendix A. Location and description of study stations

Area	Station	Location	Habitat Type
Red Bluff	RB 1	RM 242.5 L	Eroding riparian
	RB 2	RM 242.0 L	Standard riprap
	RB 3	RM 242.0 R	Sandy bank/ Gravel bar
	RB 4	RM 241.7 L	Eroding riparian
	RB 5	RM 240.8 L	Gravel bar
	RB 6	RM 241.0 R	Eroding orchard <i>freed</i>
	RB 7	RM 240.3 R	Sandy bank/ Gravel bar
Chico Landing	CL 1	RM 194.3 L	Gravel bar
	CL 2	RM 194.0 L	Standard riprap
	CL 3	RM 194.0 R	Gravel bar
	CL 4	RM 193.5 L	Eroding riparian
	CL 5	RM 193.3 R	Eroding fields <i>herbaceous</i>
	CL 6	RM 193.3 L	Gravel bar
	CL 7	RM 192.9 R	Sandy bank/ Gravel bar
RM 215	215-1	RM 227.6 L	Standard riprap
	215-2	RM 215.0 R	1V:5H slope
	215-3	RM 215.0 L	Gravel bar
	215-4	RM 215.1 R	Standard riprap
RM 227	227-1	RM 227.6 L	Standard riprap
	227-2	RM 227.5 L	1V:5H slope
	227-3	RM 227.5 R	Gravel bar